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THE BUD MOTH

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INTRODUCTION

For many years the unfolding leaves and blossom buds in the apple orchards of the northern part of the United States and of southern Canada have been seriously injured by the small brown larvæ of the bud moth, *Spilonota ocellana* (D. & S.). This bulletin presents the results of studies of this species carried on in 1920 and 1921 at the field station maintained at Wallingford, Conn., for the study of fruit insects, by the Bureau of Entomology, in cooperation with the Connecticut Agricultural Experiment Station at New Haven.[1]

HISTORICAL

The native home of the bud moth seems to be Europe, where it has been mentioned in entomological literature since 1776, when it was described by Denis and Schiffermüller (*1*)[2] under the name *Tortrix ocellana*. The bud moth was presumably introduced into the United States with the early importations of apple and other nursery stock, but no mention seems to have been made of it until 1841, when Harris (*3*) gave a short account of it under the name *Penthina oculana*. During the next 40 years only occasional short mention of the pest was made.

[1] The work of the Wallingford station has been under the direction of Dr. A. L. Quaintance. The writer was assisted in 1920 by C. H. Alden and in 1921 by H. M. Tietz. The writer wishes also to thank Carl Heinrich, of the Bureau of Entomology, for assistance in the preparation of the description of the full-grown larva, and R. A. Cushman, A. B. Gahan, and Dr. J. M. Aldrich for parasitic determinations.

[2] Numbers in parentheses refer to "Literature cited," p. 19.

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In 1856 Fitch (*7*, *p. 345–346*) mentioned it under the name *Spilonota oculana* and stated that it was probably identical with *ocellana* D. & S., *luscana* Fab., and *comitana* Hübner, Stephens, and others. In 1860 Clemens (*8*) described the species under the name *Hedya pyrifoliana*. In 1869 (*9*), in reply to a Pennsylvania correspondent of the American Entomologist, it was stated that larvæ which had been sent in for determination were probably *Spilonota oculana* (Harris), and that the species did not occur in the West. In 1871 the bud moth was reported in Ontario, and in mention of the species in 1885 Fletcher (*12*) expressed the opinion that hibernation occurred in the larval stage in tiny silken nests on the branches of the apple trees. This observation was verified by others during the course of the next few years. In 1888 Fernald (*13*) recommended the use of Paris green for the control of the pest, and in a bulletin published in 1891 (*15*) gave considerable historical information and added to our knowledge of the biology of the species. About this time the bud moth was reported from numerous additional localities in the New England States, New York, Ohio, and Michigan.

In 1893 Slingerland (*16*) published an extensive and accurate account of the bud moth, and, since the publication of his work, increasingly frequent mention has been made of the species in experiment station bulletins and other entomological literature.

About 1895 (*17*) the bud moth was reported from Genesee, Idaho, from St. Elmo, British Columbia, and within the next few years from numerous localities in the adjoining States of Montana, Washington, and Oregon, and from new localities in British Columbia.

In connection with experimental work carried on by the Bureau of Entomology in Michigan in 1913, Scott and Paine (*18*) undertook a study of a species of larva working in apple buds, assumed at that time to be the only bud moth. Before the investigation had progressed very far, however, the discovery was made that the insect under observation was not *Spilonota ocellana*, but an entirely distinct species, which was later identified as *Recurvaria nanella* (Hbn.) to which was given the name "the lesser bud moth." This species has been reported from numerous localities from Maryland to Nova Scotia, and westward to Michigan. The life history of the lesser bud moth parallels rather closely that of the true bud moth during the winter and early spring. In early spring the work in the foliage is most noticeable, and without doubt more or less of the injury attributed to *Spilonota ocellana* in the eastern portion of its range has in reality been the work of the lesser bud moth.

In 1919 Sanders and Dustan (*22*) published an account of the bud moths in Nova Scotia, and added two more species, *Cacoecia rosaceana* (Harris) and *Olethreutes consanguinana* Wlsm., to the two already known to winter as larvæ in silken hibernacula and to feed in the unfolding buds in the spring.

SYNONYMY

The following list of synonyms does not include all of the numerous genera to which the species has been referred from time to time. In recent years the species for the most part has been incor-

rectly placed in the genus Tmetocera Lederer. The species *comitana* Hbn., a synonym of *ocellana* D. and S., was designated by Curtis (*2*) in 1835 as the type of the genus Spilonota Stephens. Tmetocera is, therefore, identical with the older genus Spilonota Stephens.

The variety *lariciana* Heinemann, said to have been reared in Europe from the larch, has been reared in the United States from apple foliage, but there is no American record of it as a larch feeder.

Spilonota ocellana (D. & S.)

Tortrix ocellana Denis and Schiffermüller, 1776, *in* Syst. Verzeichn, Schmett. Wien, p. 130.

Pyralis luscana Fabricius, 1794, *in* Ent. Syst., t. 3, p. 2, p. 255.

Tortrix comitana Hübner, 1800, *in* Samml. Eur. Schmett., v. 5, Lepidop, VII, Tortrices II, pl. 3, fig. 16.

Spilonota comitana (Hübn.) *in* Stephens, 1829, Cat. Brit. Insects, pt. 2, p. 174, No. 6914.

Penthina oculana Harris, 1841, *in* Treatise on Insects, p. 348–349.

Tmetocera ocellana (D. & S.) *in* Lederer, 1859, Wien. Ent. Monatschr., Nr. 12, Band 3, p. 367–368.

Hedya pyrifoliana Clemens, 1860, *in* Proc. Phil. Acad. Sci., p. 357.

var. lariciana Heinemann 1863, *in* Schmett. Eur. Deutsch., Bd. 1, Heft. 1, Abth. 2.

COMMON NAME

This insect has been variously called the bud moth, the bud worm, and the eye-spotted bud moth. The last name has been very generally used, and refers to certain more or less eyelike markings on the forewings of the moth. The moths themselves, however, are seldom noted by any but entomologists, and the first part of this name has little significance to the average fruit grower, although he is usually all too familiar with the work of the larvæ in the fruit buds. The name officially adopted for this species by the American Association of Economic Entomologists is the bud moth, and this name will be used in this bulletin.

FOOD PLANTS

The following list of food plants, which has been brought together from all available sources, shows the bud moth to be a very general feeder.

Alnus sp.[3]	Alder.
Carpinus sp.	Hornbeam.
Crataegus sp.	Hawthorn.
Chaenomeles lagenaria (Loisel.)	Japanese quince.
Cydonia oblonga Mill.	Quince.
Fagus sylvatica purpurea Ait.	Purple beech.
Larix sp.[3]	Larch.
Myrica gale L.[3]	Sweetgale.
Amygdalus persica L.	Peach.
Prunus spp.	Cherry, plum, prune, etc.
Pyrus communis L.	Pear.
Malus sylvestris Mill.	Apple.
Pyrus spp.	Flowering crab, crab apple, etc.
Quercus imbricaria Michx.	Shingle oak.
Quercus sp.	Oak.
Rubus spp.	Blackberry, raspberry.
Sorbus aucuparia L.[3]	European mountain-ash.

[3] Recorded as a food plant in Europe but not in North America.

DISTRIBUTION

The exact distribution of the bud moth has been difficult to ascertain, as the unfortunate confusion of the bud moth with numerous species similar to it has doubtless given rise to a number of erroneous records. The map (fig. 1) shows the distribution of this species in North America as indicated by available records.

The extension of the range of the bud moth south of the District of Columbia is based on reports in the correspondence files of the Bureau of Entomology of its presence at Amherst Court House and Waldrop, Va., Oakwoods, N. C., and McIntyre, Ga. Through this section the pest is apparently present at most in very small numbers. A similar condition seems to exist in the Middle West. R. L. Webster writes from North Dakota that he has no definite record of the bud moth from that State. Fracker writes that, while the bud moth has

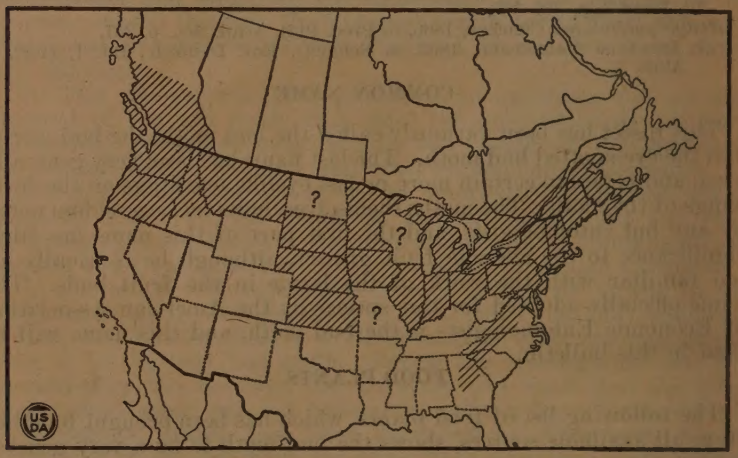
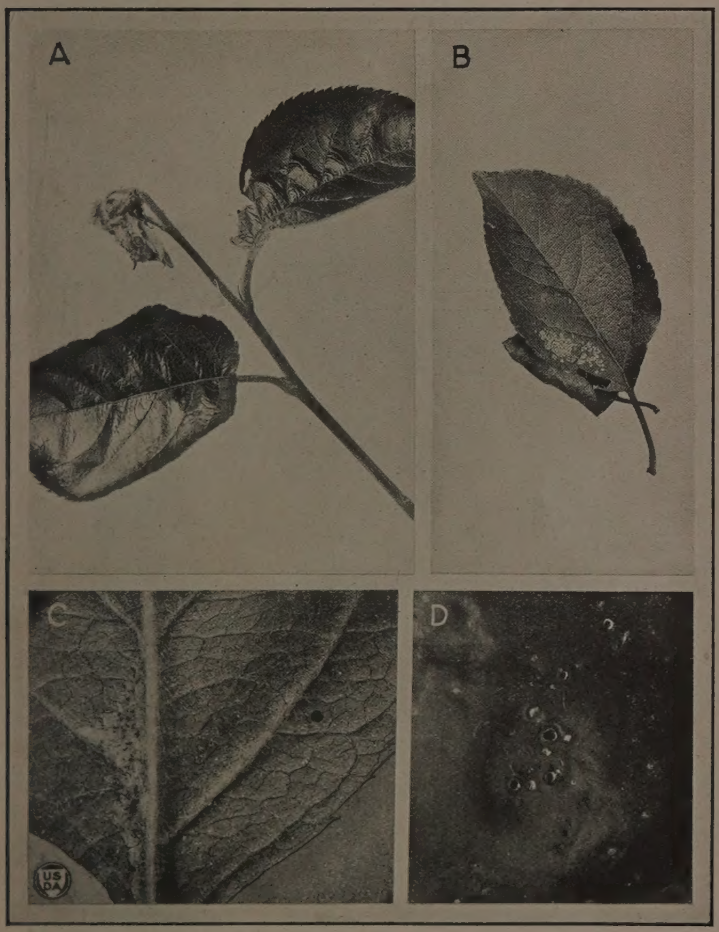


FIG. 1.—Distribution of the bud moth in North America

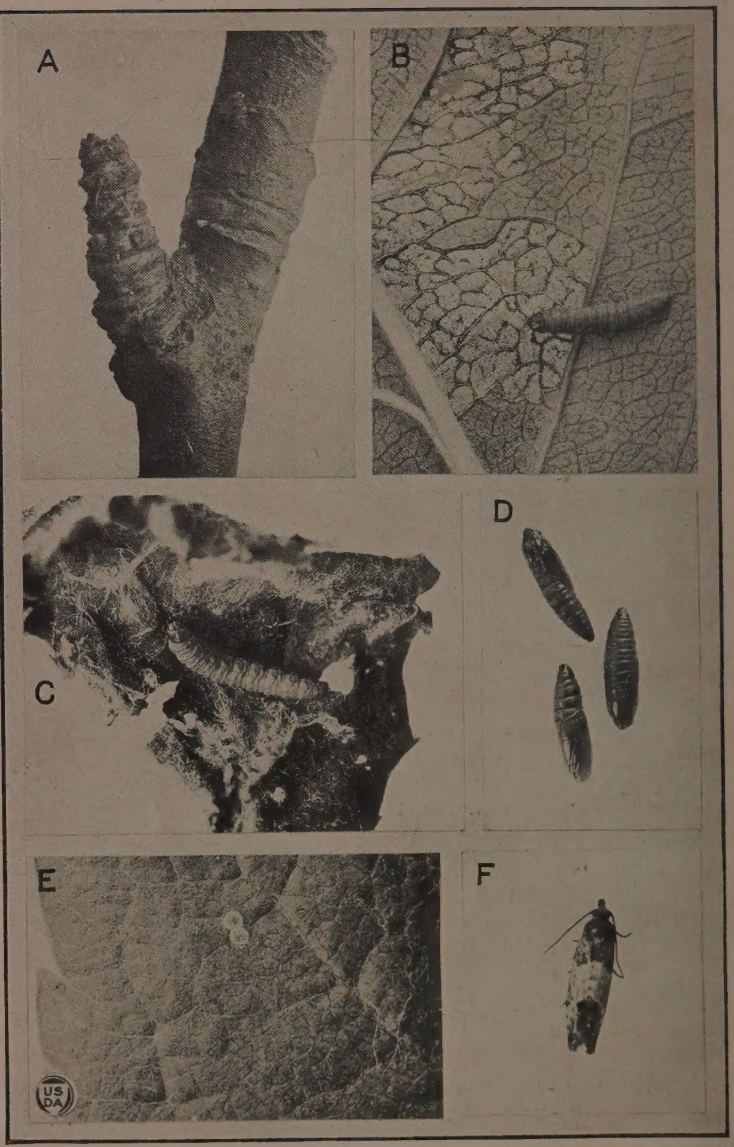
been mentioned as occurring in Wisconsin, specimens accompanying such reports have always turned out to be the leaf crumpler, *Mineola indigenella* Zeller. Haseman, writing from Missouri, states that there seem to be no official records of the presence of *Spilonota ocellana* in that State. Dwight Isely, formerly of this bureau, reports that in the course of extensive collecting he has never seen the bud moth in Arkansas, or anywhere in the Ozarks. The pest is mentioned in experiment station publications from the other midwestern States, but apparently is not present in serious abundance. The areas of most serious infestation seem to be southeastern Canada, the Northeastern States, northwestern group of States, and British Columbia.

The bud moth is said to occur throughout the British Isles and Europe, except in the most southern countries.



WORK OF THE BUD MOTH

A, One type of spring foliage injury (× ½); B, late summer foliage injury (× ⅔); C, summer feeding shelter (× 2½); D, late summer injury to the fruit (× 2)



BUD MOTH

A, Hibernaculum (× 3½); B, nearly full-grown larva on leaf (× 2½); C, full-grown larva in torn-open nest in dead leaf (× 2½); D, pupæ (× 3); E, eggs on leaf (× 4); F, moth (× 2½)

MEANS OF DISSEMINATION

While fairly extensive local distribution of this insect may be effected by the flight of the moths, by far the most important factor in its widespread dissemination has been the ease with which it may be carried on nursery stock, owing to the difficulty of detecting it during the dormant season. The hibernacula are usually tucked away in some inconspicuous crevice or corner. Even when not so concealed they are difficult to find, so closely do they resemble the surrounding bark. There is no doubt that this pest owes its present extensive distribution largely to the fact that it has been repeatedly transported to new localities on stock from infested nurseries, both from this country and from Europe.

ECONOMIC IMPORTANCE

Although usually placed among the lesser insect pests of the apple, the bud moth often does serious damage, and its importance is usually underestimated. The commercial loss caused by this species has been estimated to be as high as 30 per cent in severe infestations, although a loss as great as this is doubtless unusual. In the spring the half-grown larvæ feed to some extent in the unopened blossoms, reducing very materially the amount of fruit which sets and causing in years of light crops an especially serious loss, the extent of which is seldom fully realized. When larvæ are numerous the leaves may be considerably injured, much foliage being used for the larval nests in addition to the amount actually consumed. Larvæ sometimes ruin the growing shoots by killing the terminal leaf for use as a nest, or by burrowing inside the shoot. After the fruit sets it is occasionally eaten into by the nearly full grown larvæ, and drops off or becomes deformed and disfigured. In late summer the foliage injury by the tiny worm (Pl. I, B) is not as extensive or as serious as in the spring, but the larvæ often feed to some extent on the fruit, making numerous small, shallow blemishes (Pl. I, D).

OTHER SPECIES OF BUD MOTH

A few of the numerous leaf-feeding species of insects infesting apple foliage in early spring have certain life-history details in common with the bud moth, and are likely to be confused with it. Short accounts of a few of these species follow.

LESSER BUD MOTH

The lesser bud moth, *Recurvaria nanella* (Hbn.) (*18*), until 1914 was confused with the bud moth, and very possibly its work is often still identified as being that of *Spilonota ocellana*. The lesser bud moth winters over in hibernacula very similar to those constructed by the bud moth, although not always placed as close to the buds. Larvæ of this species emerge a few days earlier in the spring than those of the bud moth—sometimes before the buds have expanded to any extent. Their feeding shelters in the leaves are usually constructed in living rather than dead foliage. On emergence from

hibernation, larvæ of this species are often mistaken for those of *Spilonota ocellana*, but are a more reddish brown, which later turns to greenish brown or green. In the late summer the young larvæ are leaf-miners, and are not likely at this time to be confused with the bud moth.

OBLIQUE-BANDED LEAF-ROLLER

In Nova Scotia (*22*) the oblique-banded leaf-roller, *Cacoecia rosaceana* Harris, winters over as a partly grown larva in a hibernaculum similar to that made by other species of bud moth, but smaller, and more often constructed under a dead bud scale. At Wallingford, Conn., a single moth of this species was reared from a larva which emerged early in the spring of 1922 from a similar hibernaculum. Emergence from hibernation takes place in the spring at the same time as that of the lesser bud moth. The larva at this time is dirty yellow to brownish. After the leaves expand, this species feeds as a leaf-roller, and is not likely to be confused with the bud moth.

OLETHREUTES CHIONOSEMA Zeller

Adults of this species were reared at Wallingford, Conn., in 1921 from larvæ found in the buds just as they were unfolding in the spring, and in 1922 from larvæ emerging from winter shelters very similar to bud moth hibernacula.

GREEN BUDWORM

The green budworm, *Olethreutes consanguinana* Wlsm., has been reported as an apple feeder in Nova Scotia (*22*) only. It winters as a partially grown larva in a hibernaculum, much as do the other species already mentioned. After emergence in the spring, a confusion with other species of bud moth is not very probable. The larvæ of this species are green with a black head, and in the spring they feed as leaf-rollers, not confining themselves as closely to the nests as does the true bud moth.

THE LEAF CRUMPLER

The leaf crumpler, *Mineola indigenella* Zeller, hibernates as a partly grown larva. Its winter shelter, which is larger and much more conspicuous than that of the bud moth, is tubular and often hidden in a small mass of crumpled leaves. The larva is considerably larger than that of the bud moth, but its color is somewhat similar.

DESCRIPTION OF STAGES OF THE BUD MOTH

EGG

Pl. II, *E*

Flattened, rounded oval in shape, varying somewhat in outline. Length 0.72 to 0.99 millimeter, average 0.83; width 0.55 to 0.77 millimeter, average 0.67. Pale watery white in color, almost transparent when first laid, with an iridescence in some lights. Faintly sculptured with reticulate lines, which are more clearly visible along the edges. As the development of the embryo progresses, the egg material shrinks from the edges, leaving a thin, narrow flange-like margin.

LARVA

In Wallingford some individuals passed through six larval instars and others through seven, but except for a slight difference in size there seem to be no noticeable differences between the two.

Full-grown larva (Pl. II, *B*, *C*).—Width of head 0.94 to 1.16 millimeters; average 1.05. Length 11 to 13 millimeters. General color dull brown; head from medium brown to nearly black, shiny; thoracic shield shiny, dark brown to black, divided in the middle by a longitudinal paler line; mouth parts brown, lighter than head; antennæ pale at base, darker at tips; anal shield dark; ventral surface paler than dorsal; thoracic legs dark brown, almost black, shiny; prolegs pale, crotchets biordinal and in a complete circle, 32 to 48 in number; surface of body finely granulate; tubercles darker than surrounding body surface, finely lined, shiny, with darker dots at bases of setæ; chitinization about thoracic tubercles very large; three setæ on prespiracular shield of thorax in longitudinal line; setæ IV and V on proleg-bearing abdominal segments under spiracles closely approximate and on the same chitinization; paired setæ II on ninth abdominal segment on one chitinization and closer together than paired I on dorsum of eighth abdominal segment; II and III on ninth abdominal segment on the same chitinization and closely approximate; eighth abdominal seta III directly anterior to spiracle; a short, small anal fork with 2 to 5 prongs of irregular length.

First stage.—Width of head 0.22 millimeter; length when newly hatched 1.05 to 1.27 millimeters; length when full fed about 2 millimeters. When newly hatched, the larva is white; head shiny black; thoracic shield very dark gray, almost black; anal plate gray, paler than thoracic shield; ventral surface much the same color as dorsal; thoracic legs dusky; prolegs concolorous with the body. Body with sparse, long, white hairs. After feeding a few days the larva becomes a dirty yellowish white, and then light brown.

Second stage.—Width of head 0.28 to 0.39 millimeter, average 0.33; length when full fed 2.5 to 3 millimeters. General color light brown; head very dark brown to black, shiny; thoracic shield the same; anal shield darker brown than the body, but not nearly as dark as thoracic shield; venter much the same color as dorsal surface; thoracic legs very dark brown to black, shiny; prolegs concolorous with the body; tubercles distinct; hairs creamy white, moderately long, sparse.

Third stage.—Width of head 0.39 to 0.52 millimeter; average 0.45. Length when full fed 3.5 to 4 millimeters. General color dull brown; head a shiny black; thoracic shield shiny, very dark brown, practically as dark as head; anal shield dark brown, shiny; ventral surface not quite so dark a brown as dorsal; true legs dark brown; prolegs somewhat paler than adjacent body surface; tubercles distinct, shiny; hairs moderately long, sparse, white.

Fourth stage. (Hibernation usually occurs in this instar, the larva molting during the construction of the hiberculum.)—Width of head 0.41 to 0.55 millimeter, average 0.50; length in hibernating condition about 3 millimeters; length when full fed after emergence in the spring about 5 millimeters. Body color an almost uniform cinnamon brown, with some variation from darker to lighter; head and thoracic shield a dark shiny brown, head a little darker, almost black; thoracic shield a little lighter on anterior margin; anal plate from concolorous with the body to a little darker; thoracic legs a somewhat darker brown than the body; prolegs concolorous with the body; mouth parts brown, paler than head; tubercles conspicuous, concolorous with the body, shiny; hairs sparse, short, white.

Fifth stage.—Width of head 0.66 to 0.80 millimeter, average 0.71; length when full fed 7.5 to 8.5 millimeters. General color a dull brown, sometimes with an olivaceous tinge; head and thoracic shield dark brown to black, shiny; mouth parts brown; antennæ pale basally, darker toward tips; anal plate dark greenish brown; ventral surface not quite so dark as dorsal; thoracic legs piceous, shiny; prolegs about concolorous with the ventral surface, with a dark area on outer side; tubercles with a minute dark dot; hairs sparse, white.

PUPA

Pl. II, *D*

Female.—Length 6 to 7 millimeters; width at widest point 1.8 to 2 millimeters. Color golden brown, deeper at head, wing pads, anal segment, and

spiracles. Dorsal abdominal segments 2 to 7 each with two transverse rows of short bristles pointing backwards, one row near each margin of the segment, that on the anterior margin frequently overlapped and concealed by the segment anterior to it. Spines in the posterior row of each segment much smaller than those in the anterior row. Dorsal segments 8 to 10 each with a single row of spines; those on segment 9 somewhat stouter, and those on segment 10 very much stouter than those on other segments. Cremaster absent; anal segment with 8 bristles, curved outward at their tips, arranged somewhat in a circle, four singly and two pairs. Abdomen minutely pitted. Spiracles somewhat raised and rounded.

Male.—Same as female, but a little smaller.

MOTH

Pl. II, *F*

Fernald (*15*) describes the moth as follows:

The fore wings expand about three-fifths of an inch. The head, thorax and basal third of the fore wings, and also the outer edge and fringe are dark ash gray, the middle of the fore wings is cream white, marked more or less with costal streaks of gray, and in some specimens this part is ashy gray, but little lighter than the base. Just before the anal angle are two short horizontal black dashes followed by a vertical streak of lead blue, and there are three or four similar black dashes before the apex, also followed by a streak of lead blue. The hind wings above and below and the abdomen are ashy gray. The under side of the fore wings is darker, and has a series of light costal streaks on the outer part.

SEASONAL HISTORY AND HABITS

The bud moth has one generation every 12 months, commencing with the egg stage in midsummer and ending with the deposition of eggs for the succeeding generation during midsummer of the following calendar year.

It passes the winter as a partially grown larva in a tiny silken nest, or hibernaculum (Pl. II, A), placed in any convenient crevice, or other place. Du Porte (*19*) found that in Quebec hibernation occurred in the third, fourth, and fifth stages. Under Connecticut conditions practically all larvæ enter hibernation at the end of the third stage and molt during the construction of the hibernaculum, although occasionally a few individuals pass the winter in the following stage.

Emergence from hibernation occurs early in the spring, sometimes as the buds are just beginning to show green, but more often a little later, as the buds are unfolding. In Connecticut the lesser bud moth, *Recurvaria nanella*, which at this point in its life history follows closely that of the bud moth, has a tendency to emerge earlier, and frequently enters the buds before they have expanded to any extent. While the bud moth occasionally emerges equally early, it is more likely to wait until the leaves are just beginning to unfold before leaving winter quarters. Once in a while a larva after emergence and a short period of feeding in an unfolding bud will return to its hibernaculum, usually because of unfavorable weather, leaving behind a trail of silk.

In 1920 and 1921, the emergence of the larvæ from hibernation was carefully observed. Infested material was brought in and short lengths of twigs which bore hibernacula were placed in cages. These were kept in the insectary under out-of-door conditions except

for a few moments each day, when the material was brought inside for examination and removal of the larvæ which had emerged. The emergence as observed by this method seemed to agree for the most part very closely with conditions noted in the field, except the latter part of the 1921 emergence, which continued intermittently for about two weeks after it was apparently complete in the field. In a few instances the presence of an opening in a hibernaculum loosely covered with fresh silk gave evidence that a larva had left its winter nest, but not finding fresh foliage in the cage, had returned to its winter quarters to await more favorable conditions. With this exception, Table 1 undoubtedly indicates very closely what was occurring in the field. In 1920 the season was approximately two weeks later than the normal season, but from May 6, when the bud moth larvæ commenced leaving their winter quarters, the weather continued fairly warm, and evidently favored rapid emergence. In 1921 the season was on the whole two weeks ahead of normal, but the extreme warm periods alternated with cooler weather, which explains in part the straggling emergence which occurred.

TABLE 1.—*Emergence of the bud moth from hibernation, Wallingford, Conn.*[1]

IN 1920

Date	Number emerged	Temperature			Date	Number emerged	Temperature		
		Maximum	Minimum	Average			Maximum	Minimum	Average
		° F.	° F.	° F.			° F.	° F.	° F.
May 3		53	39	44.7	May 9	17	72	47	59.3
4		50	35	42.6	10	5	75	49	59.1
5	1	62	31	46.3	11	7	66	49	54.7
6	16	68	36	51.5	12	4	66	44	56.0
7	11	68	41	53.8	13	4	57	47	50.5
8	11	53	48	51.0	14	2	54	45	48.7

IN 1921

		° F.	° F.	° F.			° F.	° F.	° F.
Apr. 4		70	42	55.3	Apr. 22	3	78	49	60.9
5		81	49	64.1	23	5	64	45	52.2
6	2	78	50	62.0	24	6	67	42	54.3
7		46	39	41.5	25	3	76	47	59.2
8	5	58	39	47.3	26		73	44	57.6
9	7	71	46	57.7	27		68	51	58.4
10		53	33	44.0	28	1	73	56	64.0
11	4	47	29	36.3	29		72	51	59.8
12	13	61	33	46.4	30		68	49	53.8
13	6	68	37	51.8	May 1	2	52	44	47.5
14	10	70	44	55.7	2	1	68	42	52.4
15	7	57	51	54.2	3		70	47	55.8
16	5	63	52	56.7	4		64	43	54.8
17	1	57	46	53.9	5		47	44	45.1
18		44	34	37.4	6	2	49	45	47.0
19	3	47	34	40.9	7	2	62	41	51.0
20	4	73	36	54.0	8	2	73	45	56.9
21	2	76	49	60.5					

[1] Temperatures in Table 1 are from thermograph records; 24 hourly temperatures used in calculating [illegible]

On emerging from winter quarters the larva makes its way to a bud or an unfolding cluster of leaves. If the bud has not yet

opened, the larva chews its way into it from the outside, but if the leaves are unfolding, as is usually the case, it makes its way into the heart of the cluster, leaving little external evidence of its presence. When not feeding, it conceals itself in any convenient place—the curled edge of an unexpanded leaf, or among the stems at the base of the cluster. After feeding for a short time, sometimes in the unopened blossom buds, and sometimes on the foliage, the larva constructs a tubular nest, usually in a fold or the curled portion of a leaf, sometimes between two leaves which touch. All large gaps are closed, and the nest is lined with silk, in which are frequently embedded bits of leaf tissue and more or less frass. The leaf in which the nest is constructed is often partially severed at the base, causing it to wilt and turn brown, and is usually attached with silk to an uninjured leaf or stem, which prevents the nest from falling when the leaf dies. Sometimes the nest is made in the terminal leaf of a shoot (Pl. I, A). While the leaf in which the nest is constructed is still green, the larva feeds on it, but as the leaf dies and becomes dry the larva goes out to feed on adjacent leaves, at first skeletonizing small areas on either surface of the leaf, and later sometimes consuming entire sections of leaf. In some cases the larva burrows into and down one of the growing shoots, causing the tip to die. While the larval nests are occasionally constructed in other places, the great majority of them are to be found in dead leaves. The lesser bud moth and the leaf-rollers are more likely to make their headquarters in living leaves, which are rolled, curled, folded, or tied, as the case may be. The lesser bud moth often webs together the tip of the leaf cluster, which bulges out as the leaves grow. Occasionally the bud moth will desert its nest and construct another.

Efforts to observe closely the successive molts as they occurred have been only partially successful, as the unavoidable necessity of disturbing the larvæ in their nests for the purpose of making observations brings about a high mortality. By starting with a large number of individuals, however, it was determined in the spring of 1921 that some of the larvæ molt twice in the spring and others three times, except in the occasional instances where hibernation is delayed until the fifth stage, in which case the number of molts in the spring is one less than usual. This makes the number of stages six in some cases, and seven in others. Sixth-stage larvæ which are to pass through a seventh stage are somewhat smaller than those completing their development in the sixth stage, but the measurements overlap, and it is impossible to determine to which stage a nearly full-grown larva belongs, unless observations have been made at regular intervals since emergence from hibernation.

Besides feeding on the leaves and growing shoots, the larvæ when nearly full-grown occasionally attack the newly set fruit, causing it to drop off, or become deformed and disfigured by an extensive corky area.

When the feeding period is at an end, the larva makes preparations for pupation. In some cases it remains in its feeding shelter; in others it deserts this place, and finds another sheltered spot, in a

curled leaf, or elsewhere, and lines the place chosen with silk. At this time the larva loses much of its brown color, becomes a dirty grayish white, and also becomes somewhat shortened. In this condition it may continue several days or even a week before pupation finally takes place.

In both 1920 and 1921, a number of larvæ were collected in the field when nearly full grown, and the exact dates of pupation and emergence were noted, the resulting data being presented in Table 2.

TABLE 2.—*Pupation and emergence of the bud moth, Wallingford, Conn.*

IN 1920

Pupated	Emerged	Number of individuals	Days	Pupated	Emerged	Number of individuals	Days
June 3	June 24	1	21	June 22	July 8	3	16
11	29	1	18	23	8	3	15
12	29	3	17	24	8	1	14
13	29	2	16	24	9	2	15
13	July 1	2	18	24	10	4	16
14	1	3	17	25	9	1	14
15	1	2	16	25	10	3	15
15	2	2	17	25	11	1	16
15	3	1	18	26	11	1	15
16	3	1	17	26	12	1	16
16	4	1	18	27	12	3	15
16	5	2	19	28	12	2	14
17	4	1	17	28	14	1	16
17	5	2	18	29	14	1	15
20	7	2	17	30	14	4	14
21	8	1	17	July 2	16	1	14
22	7	2	15	11	24	1	13

IN 1921

May 28	June 15	1	18	June 13	June 28	2	15
31	18	1	18	13	30	1	17
31	20	1	20	14	29	1	15
June 3	20	1	17	15	29	1	14
3	21	2	18	15	30	1	15
5	23	1	18	15	July 1	1	16
6	22	1	16	16	1	2	15
6	24	1	18	16	2	1	16
7	22	1	15	19	3	2	14
7	24	1	17	19	4	1	15
7	25	2	18	20	3	1	13
8	23	1	15	20	4	1	14
9	24	1	15	21	4	2	13
10	24	1	14	22	6	1	14
10	25	1	15	23	7	1	14
11	25	2	14	23	8	1	15
11	26	1	15	24	8	2	14
11	27	3	16	26	9	2	13
12	26	1	14	July 3	15	1	12
12	27	2	15	3	16	1	13
12	28	1	16				

Table 3 gives data regarding the duration of the period of pupation under Connecticut conditions in 1920 and 1921, summarizing Table 2. The period varies from 12 to 21 days, with an average of 15 to 16 days.

TABLE 3.—*Period of pupation of the bud moth, Wallingford, Conn., 1920 and 1921—Summary of Table 2*

Number of days	Number of individuals	
	1920	1921
12 days	0	1
13 days	1	0
14 days	9	12
15 days	15	15
16 days	14	7
17 days	13	3
18 days	7	8
19 days	2	0
20 days	0	1
21 days	1	0
Total	62	53
Average number of days	16	15.3

The emergence of the moths covers a period of a month or more, following from two to three weeks after pupation. In 1920, the moths were emerging in the insectary from June 24 to July 24; in 1921, a single moth was noted in the field on June 8, and moths emerged in the insectary from June 15 to July 16.

The moths are active chiefly at night, and are not often noted in the daytime. Mating was not observed in the insectary at Wallingford, but apparently occurred at night, and fertile eggs were laid in fair numbers in the jars used for oviposition. Egg-laying commenced in from 2 to 5 days after emergence, usually on the second or third day, and continued from 1 to 11 days, although the greater part of the eggs were usually laid during the first 2 or 3 days of oviposition. Confined in battery jars, some of the moths refused to lay at all; others deposited a few eggs, while others laid very freely. The greatest number of eggs laid by any one moth was 156. Eggs were deposited on both sides of apple or pear foliage, usually singly, but occasionally several overlapping one another. In captivity one female moth lived 15 days and a male 16 days, the average length of life in 1920 being 7.5 days for the females and 7 days for the males. In 1921 the average was 11.6 days for the females and 12.2 days for the males.

Four or five days after the eggs are laid, the exact length of time depending upon weather conditions, certain changes become evident. At this time two dark dots become visible through the thin shell of the egg, indicating the presence of the two groups of ocelli. In six or seven days the brown mandibles and other mouth parts appear; shortly afterwards the dark head and thoracic shield become evident, and the outline of the larva becomes very faintly visible. At the end of the seventh day occasional larvæ hatch if the weather has been especially warm, but the greater part of them hatch in 8 to 10 days, the incubation period, according to Table 4, being approximately 9 days under ordinary midsummer conditions in Connecticut.

TABLE 4.—*Incubation of eggs of the bud moth, Wallingford, Conn., 1920*

Eggs laid	Eggs hatched	Number of eggs	Days
July 8	July 15	29	7
	16	15	8
9	17	18	8
10	19	19	9
	20	27	10
11	20	8	9
12	21	73	9
	22	9	10
13	22	93	9
14	23	124	9
15	24	21	9
	25	29	10
Total eggs		465	
Average incubation period			9

After hatching, the larva wanders about on the leaves for a short period. During this time it may gnaw small pits in the leaf tissue and spin a small amount of silk, but it soon settles in one spot and constructs a shelter. This may be located anywhere on either surface of the leaf, but the preference seems to be for the lower surface next to one of the larger veins or the midrib, although often the place chosen is where two leaves or a leaf and an apple touch. The larva then constructs a weblike shelter over itself and the greater part of its feeding grounds, often embedding in the silk more or less frass, bits of leaf tissue, and leaf hairs. Later in the stage the shelter takes the form of a tube open at both ends under a rooflike silken web (Pl. I, C). When newly hatched the larva is white, but after a few days of feeding it becomes first a dirty yellowish white, and then a light brown. As the larva grows, the amount of frass included in the tubular portion of the nest increases until it becomes dark brown or black, while the flat web above is light, loosely woven, and includes only a few loose bits of frass. If constructed next to a straight midrib or vein, the tube is straight; in other cases it may be more or less curved and irregular in shape. In feeding, the larva eats through to the opposite epidermis, which becomes dry and brown. As feeding continues and the larva increases in size, the shelter is extended to cover most of the feeding ground, and the tubular nest is lengthened. If the nest has been constructed between a leaf and an apple, the larva frequently gnaws tiny pits through the skin of the fruit. If feeding takes place between two leaves the leaves are webbed together, and if next to an apple the leaf is fastened to it. As feeding continues the area consumed is increased, but the larva very rarely eats through the opposite epidermis of the leaf. All larvæ observed passed through at least three stages, and in rare cases four, before entering hibernation.

Several weeks before the coming of cold weather, as the larvæ approach the end of the third or rarely the fourth stage, they begin to desert the leaves to seek quarters for the winter. The earliest date on which larvæ were found in hibernation in Connecticut in the summer of 1920 was August 21; in 1921 it was August 25, and it was six weeks or more before all larvæ had left the leaves. In 1921 infested twigs were brought in at intervals and record made of the number of larvæ in hibernation and those still feeding. These ob-

servations, expressed in percentages, are presented in Table 5. Extremely cool weather apparently has little to do with the entering of the larvæ upon the hibernation period, as up to September 30, the date on which nearly all larvæ had left the foliage, the lowest minimum temperature had been 44° F., on September 27.

TABLE 5.—*Hibernation of the bud moth, Wallingford, Conn., 1921*

Date of observation	Percentage of larvæ in hibernation	Date of observation	Percentage of larvæ in hibernation	Date of observation	Percentage of larvæ in hibernation
Aug. 19	0.0	Sept. 16	31.3	Oct. 5	95.0
25	14.3	19	31.8	10	96.8
Sept. 1	12.5	26	72.7	15	100.0
7	30.0	30	93.8		

The winter nest (Pl. II, A) is most often placed in the angle at the base of a fruit spur or a short twig, but may be constructed under a dead bud scale, in a crevice in the bark, or in any other convenient location. The hibernaculum is elongate, from 3 to 5 millimeters long and from 1 to 2 millimeters wide, and is either straight or curved, to conform to the space in which it is constructed. Included in the outer layer are bits of frass and tiny pieces of bark or bud scales, and after the nest is closed in the surface is very nearly of the color of the surrounding bark and hard to distinguish from it. The inner layers of the winter nest are of fine white silk without any foreign matter. During the construction of the hibernaculum the larva molts, as evidenced by the presence of the cast skin and head capsule, which are found at one end of the hibernaculum, usually between the outer and inner layers of silk, but sometimes visible from the outside and partially woven into the outside layer. Some larvæ are found facing away from the old cast skin, and others facing toward it.

This molt is not accompanied by the usual increase in head measurement, the average width increasing from 0.45 to only 0.50 millimeter, but the presence of the cast skin is proof that the molt has occurred.

Securely inclosed within this protecting nest, the larva passes the winter, awaiting the coming of spring and the development of the tender young foliage and succulent blossom buds.

NATURAL ENEMIES

PREDATORS

Comparatively few records seem to have been made of predacious enemies of the bud moth. Birds have been mentioned as feeding on the larvæ. Slingerland (*16*) reports finding the mud nests of the wasp *Odynerus catskillensis* Sauss. stored with larvæ of the bud moth and one other species. Wilson and Moznette (*20*) report an undetermined carabid beetle, an anthocorid bug (*Triphleps* sp.), and a mite (*Anystis agilis* Banks) feeding on larvæ of the bud moth.

PARASITES

Owing to the fact that the lesser bud moth, and numerous other species, have been to some extent confused with the bud moth, it

seems possible that some of the parasites said to have been reared from *Spilonota ocellana* have been in reality parasites of *Recurvaria nanella* or of some other species. More than a score of parasites are on record as having been reared from the bud moth.

European Records

The following parasites have been recorded in Europe from the bud moth:

(*Microdus*) *Bassus dimidiator* (Nees) (*11, p. 165*); (*Microdus*) *Bassus rufipes* (Wesm.) (*5, p. 47*); *Meteorus ictericus* (Nees) (*11, p. 163*); *Chelonus nigrinus* Ratzb. (*4, p. 43*); *Chelonus similis* Nees (*4, p. 42*); *Bracon geniculator* Nees (*6, p. 34*); *Hemiteles necator* Grav. (*6, p. 154*) listed as a parasite of either *Spilonota ocellana* or *Tortrix variegana*, being possibly a secondary parasite; (*Pimpla*) *Apechthis rufata* (Grav.) (*6, p. 101*); *Lissonota culiciformis* Grav. (*10, p. 308*); *Limneria lineolata* (Ratzb.) (*11, p. 163*); *Mesochorus dilutus* Ratzb. (*4, p. 148–149*).

North American Parasites

Egg parasites

Trichogramma minutum Riley was reported by DuPorte (*19*) from numerous localities near Quebec, destroying in some cases as many as 77 per cent of the eggs. Many specimens have also been reared in Nova Scotia (*22*).

One mymarid was reared from a bud-moth egg in Nova Scotia (*22*).

Larval and pupal parasites

Secodella sp. (probably new) was reared in August, 1921, at Wallingford, Conn., from small bud moth larvæ. The same species was also reared from bud moth hibernacula in the spring of 1920 and again in the spring of 1921. This suggests the possibility of two generations of this parasite annually, one attacking the tiny bud moth larvæ soon after hatching, and the second attacking the host larvæ some time prior to hibernation. Growth of the parasite larva is completed in the late fall after the host hibernaculum is constructed, and hibernation occurs in the larval stage. Determination of these parasites was made by A. B. Gahan.

Other larval and pupal parasites have been recorded as follows:

Apanteles tmetocerae Mues. was reared from bud moth larvæ in Nova Scotia (*23 p., 560*). *Opius* (*Biosteres*) sp. was reared from pupæ (*19, p. 76*). (*Microdus*) *Bassus carinoides* (Cress.), first reported by Riley and Howard from Canada (*14, p. 18*) was reared by DuPorte (*19, p. 76*) from pupæ of the bud moth. At Wallingford three individuals of this species were reared in 1920 and one in 1921, but in all cases the parasite larva left the host larva when the host was nearly full-grown. The Wallingford material was determined by R. A. Cushman. (*Microdus*) *Bassus laticinctus* (Cress.) was reported by Slingerland (*16, p. 22*) as a common parasite, reared from larvæ of the bud moth. (*Microdus*) *Bassus ocellanae* (Rich.) was reared at Kentville, Nova Scotia (*22, p. 23*). *Chelonus* sp. is the most numerous parasite of the bud moth in Nova Scotia (*22, p. 23*). (*Pimpla*) *Itoplectis conquisitor* (Say) was reared from bud moth pupæ in Quebec (*19, p. 76.*) (*Pimpla*) *Epiurus* near *alboricta* Cress. was recorded by Slingerland (*16, p. 22*) from larvæ in July, 1892. A single individual of *Epiurus indagator* (Walsh) was reared at Wallingford, Conn., in 1920, and another in 1921 from fifth-stage larvæ. It was determined by R. A. Cushman. *Phytodictus* [*Phytodictus*] *vulgaris* Cress. was recorded by Fernald (*15, p. 9*) as an external feeder on host larvæ. *Anomalon*

sp. was reported from Nova Scotia (*22, p. 23*). Two individuals of *Winthemia quadripustulata* (Fab.) were reared at Wallingford from pupæ from bud moth larvæ which were collected in the field when nearly full-grown. They were determined by Dr. J. M. Aldrich.

CONTROL

A study of the life history of the bud moth suggests as the most favorable opportunity for its control the spring feeding period, as during this time the larvæ feed to a considerable extent on exposed leaf tissue.

During the hibernating period the larva is protected by a compactly woven silken shelter, and even the strong solutions used in dormant spraying are not likely to penetrate to the larva. Scott and Paine (*18*) report that applications of lime-sulphur and soda-sulphur solutions at dormant strength had no effect on the larvæ of the lesser bud moth while they were still in their hibernacula. Working with the bud moth, Wilson and Moznette (*20*) found that oils applied during the dormant season had no effect on the protected larvæ. In December, 1921, at the Wallingford station, a small number of twigs bearing hibernacula were dipped in the solutions usually used for dormant apple spraying: Lime-sulphur 1 to 9, the same with the addition of nicotine sulphate 1 to 800, and a miscible oil 1 to 15. This was done on a warm day, and the twigs were placed out of doors under normal conditions. Examination two weeks later showed that none of the larvæ had been affected by the treatment. The experimental evidence just cited is sufficient to indicate that little is to be expected from dormant applications.

For the control of the lesser bud moth, the so-called delayed dormant application of lime-sulphur, put on as the buds are showing a small amount of green, was effective, presumably acting as a repellent, keeping the newly emerged larvæ from entering the buds. With the bud moth, however, emergence from hibernation occurs a few days too late for the effective use of this treatment, as in Connecticut, at least, few of the larvæ leave winter quarters before the leaves have begun to unfold. DuPorte (*21*) reports a similar observation in Quebec.

Experiments were conducted on a limited scale at Wallingford with applications at the time when the apple blossoms showed pink, and again at the time of the usual calyx application.

On April 21, 1921, about the time the blossom buds were showing pink, a number of infested apple twigs were brought in; 23 of them were sprayed with powdered arsenate of lead, 1 pound in 50 gallons, and 17 were left as checks. After being sprayed the twigs were placed in water, to keep them fresh, and examined on April 27. At the time of this experiment the characteristic bud moth nests had not been made, and a number of lesser bud moth larvæ were included. The results are given in Table 6.

TABLE 6.—*Results of experiments in spraying apple twigs infested with the bud moth and the lesser bud moth with powdered arsenate of lead at the time the blossom buds were showing pink*

Treatment	Number of larvæ		
	Healthy	Sickly	Dead
Sprayed (23 twigs):			
Bud moth	0	2	0
Lesser bud moth	6	3	2
Check (17 twigs):			
Bud moth	6	0	0
Lesser bud moth	9	0	0

It is quite possible that some larvæ were killed by the spray, but left the foliage before dying.

On May 11, at the time of the calyx application, and some time before any larvæ had made preparations for pupation, a similar experiment was carried out. The material was examined on May 18, and the results are noted in Table 7.

TABLE 7.—*Results of calyx application on apple twigs infested with the bud moth*

Treatment	Number of larvæ		
	Healthy	Sickly	Dead
Sprayed (19 twigs)	6	5	4
Check (18 twigs)	10	0	0

In both of these tests more larvæ would undoubtedly have died if more time had elapsed before the material was examined, but the foliage was beginning to wilt, and the examination could not be further delayed. The presence of dead larvæ in the second test, however, indicated that the arsenate of lead was being consumed and was having its effects.

During the same season a number of small apple trees of several varieties in a near-by orchard were sprayed with arsenate of lead, 1 pound in 50 gallons, using a bucket pump. Each plat contained from 9 to 12 trees. One plat received the pink application only, one the calyx application only, and a third received both applications. Later on, before any larvæ had begun to pupate, all nests were removed from four count trees in each plat, and the numbers of dead, sickly, and healthy larvæ were recorded. The results are given in Table 8.

TABLE 8.—*Effect of arsenate of lead spray on small apple trees infested with the bud moth*

Plat	Treatment	Nests found	Larvæ found		
			Healthy	Sickly	Dead
I	Pink and calyx	51	3	2	5
II	Pink alone	58	11	1	0
III	Calyx alone	122	8	4	16
IV	Check	123	38	0	1

Although the experiments outlined above were conducted on a comparatively small scale, the results indicate very clearly that the arsenical sprays applied while the larvæ are feeding in the spring will kill a large percentage of them. In the field tests summarized in Table 8, a single application when the blossoms were showing pink apparently reduced the number of healthy larvæ present 71 per cent, a single application just after the petals had fallen reduced the number 79 per cent, and where both were applied the number of healthy larvæ was reduced 92 per cent. On the trees receiving the earlier application the number of nests was less than half the number found on trees receiving only the calyx application or none at all. The calyx spray comes too late to prevent much of the current season's injury, but kills a large proportion of the larvæ, and reduces the numbers of the next generation which is to feed during the summer and the following spring. No experiments were made with dusting, but a careful treatment with dust would probably be about as effective with this species as the liquid.

These results bear out for the most part those reported by the most recent workers on the bud moth. DuPorte (*21*) reports the combined efficiency of the two pre-blossom sprays and the calyx spray to be 86.5 per cent, and the efficiency of the pink and calyx treatments combined to be 80 per cent. Sanders and Dustan (*22*) report that the two most efficient spray applications for bud moth control (referring in general to the four species discussed) are: One when the leaves are the size of a dime, and a second immediately before the blossoms open. Further confirmation of the results noted above will be found in the fact that well sprayed orchards, which always receive the calyx application, and usually the pink cluster-bud spray, are seldom seriously troubled by the bud moth.

In case of a severe infestation, in addition to the pink and calyx applications it would probably be advisable to put on an arsenical spray about midway between the delayed dormant and pink applications, in order to keep the rapidly growing foliage as well coated as possible with the poison.

The hatching of the eggs extends over a period of a month or more, beginning about the middle of July under average Connecticut conditions. The tiny larvæ feed on the foliage and to a certain extent on the fruit during the remainder of the summer, but their feeding areas are small and for the most part confined to the lower surfaces of the leaves and under the shelter of a web of silk, or in protected places where fruit and leaves are in contact. Some success has been reported with the use of arsenicals against the young larvæ during this period, but in view of the fact that the bud moth may be controlled satisfactorily by the routine spring applications, the later treatments will probably seldom be necessary. If a single summer application is to be made, it will be best to wait until nearly the end of the hatching period, which would be early in August under Connecticut conditions. Care must be taken to cover with the spray the lower surfaces of the leaves, where the majority of the larvæ feed.

SUMMARY

The bud moth, *Spilonota ocellana*, which is presumably a European insect, was first noted in this country about 1841, and has become an important apple pest. It is now present over much of the northern part of the United States and southern Canada.

This species is a rather general feeder, attacking most of the deciduous fruit trees and some ornamental, shade, and forest trees.

At least five other species (the lesser bud moth, *Recurvaria nanella*, the oblique-banded leaf-roller, *Cacoecia rosaceana*, the green budworm, *Olethreutes consanguinana*, *Olethreutes chionosema*, and the leaf-crumpler, *Mineola indigenella*) winter in a similar manner, and are likely at one time or another to be confused with the bud moth.

The tiny brown larvæ emerge from hibernation for the most part as the leaves are unfolding, and feed in the expanding foliage and blossom buds. After a few days of feeding, they make nests, usually in a leaf, which later becomes dead and brown, and feed principally outside the nests. After several molts the larvæ cease feeding and construct cocoons, sometimes in the old nest, and in other cases in a new place, where they transform to brown pupæ. After a period lasting from 12 to 21 days they emerge as moths, which after a few days deposit their tiny, flattened, oval, translucent white eggs on the foliage. After 7 to 10 days these eggs hatch. The tiny larvæ are at first white, but in a few days become a dirty yellow, and later brown. The greater number of these larvæ feed on the foliage, usually on the under side of the leaf next the midrib or a large vein, constructing tubular shelters and feeding under the protection of a rooflike silken web. Other larvæ feed on the fruit, usually where it is in contact with a leaf, making small blemishes. After feeding for several weeks and molting two or three times, the tiny worms leave the foliage and construct winter shelters in crevices in the bark, under bud scales, and in other more or less concealed places. During the construction of the hibernaculum the larva molts.

Numerous parasites have been reared from the bud moth, both in North America and in Europe.

A satisfactory degree of control is usually obtained by two of the usual routine spring spray applications—the pink cluster-bud application (to which arsenate of lead, 1 pound of the dry form in 50 gallons of water, should be added), and the calyx spray, which is applied primarily for codling moth control. In exceptionally severe infestations, an arsenical should also be applied about midway between the bursting of the buds and the time when the blossom buds will show pink. An arsenical application in August will seldom be necessary, but if one is carefully applied, and the under surfaces of the leaves are covered with poison, additional protection will be secured.

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